

# **Calculation of Heater-tube Thickness in Petroleum Refineries**

API STANDARD 530  
SEVENTH EDITION, APRIL 2015

ADDENDUM 1, JULY 2019

## Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Users of this Standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

Where applicable, authorities having jurisdiction should be consulted.

Work sites and equipment operations may differ. Users are solely responsible for assessing their specific equipment and premises in determining the appropriateness of applying the Standard. At all times users should employ sound business, scientific, engineering, and judgment safety when using this Standard.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

## Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows.

**Shall:** As used in a standard, “shall” denotes a minimum requirement in order to conform to the standard.

**Should:** As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the standard.

**May:** As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

**Can:** As used in a standard, “can” denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001, [standards@api.org](mailto:standards@api.org).

# Contents

	Page
<b>1</b>	<b>Scope</b> . . . . . <b>1</b>
<b>2</b>	<b>Normative References</b> . . . . . <b>1</b>
<b>3</b>	<b>Terms and Definitions</b> . . . . . <b>2</b>
<b>4</b>	<b>General Design Information</b> . . . . . <b>4</b>
<b>4.1</b>	<b>Information Required</b> . . . . . <b>4</b>
<b>4.2</b>	<b>Limitations for Design Procedures</b> . . . . . <b>5</b>
<b>5</b>	<b>Design</b> . . . . . <b>5</b>
<b>5.1</b>	<b>General</b> . . . . . <b>5</b>
<b>5.2</b>	<b>Equation for Stress</b> . . . . . <b>8</b>
<b>5.3</b>	<b>Elastic Design</b> . . . . . <b>8</b>
<b>5.4</b>	<b>Rupture Design</b> . . . . . <b>9</b>
<b>5.5</b>	<b>Intermediate Temperature Range</b> . . . . . <b>9</b>
<b>5.6</b>	<b>Minimum Allowable Thickness</b> . . . . . <b>9</b>
<b>5.7</b>	<b>Minimum and Average Thicknesses</b> . . . . . <b>9</b>
<b>5.8</b>	<b>Equivalent Tube Metal Temperature</b> . . . . . <b>10</b>
<b>5.9</b>	<b>Component Fittings</b> . . . . . <b>14</b>
<b>6</b>	<b>Allowable Stresses</b> . . . . . <b>16</b>
<b>6.1</b>	<b>General</b> . . . . . <b>16</b>
<b>6.2</b>	<b>Elastic Allowable Stress</b> . . . . . <b>16</b>
<b>6.3</b>	<b>Rupture Allowable Stress</b> . . . . . <b>16</b>
<b>6.4</b>	<b>Rupture Exponent</b> . . . . . <b>16</b>
<b>6.5</b>	<b>Yield and Tensile Strengths</b> . . . . . <b>16</b>
<b>6.6</b>	<b>Larson-Miller Parameter Curves</b> . . . . . <b>16</b>
<b>6.7</b>	<b>Limiting Design Metal Temperature</b> . . . . . <b>17</b>
<b>6.8</b>	<b>Allowable Stress Curves</b> . . . . . <b>17</b>
<b>7</b>	<b>Sample Calculations</b> . . . . . <b>20</b>
<b>7.1</b>	<b>Elastic Design</b> . . . . . <b>20</b>
<b>7.2</b>	<b>Thermal-stress Check (for Elastic Range Only)</b> . . . . . <b>22</b>
<b>7.3</b>	<b>Rupture Design with Constant Temperature</b> . . . . . <b>25</b>
<b>7.4</b>	<b>Rupture Design with Linearly Changing Temperature</b> . . . . . <b>28</b>
<b>Annex A</b>	<b>(informative) Estimation of Allowable Skin Temperature, Tube Retirement Thickness, and Remaining Life</b> . . . . . <b>A-1</b>
<b>Annex B</b>	<b>(informative) Calculation of Maximum Radiant Section Tube Skin Temperature</b> . . . . . <b>B-1</b>
<b>Annex C</b>	<b>(normative) Thermal-stress Limitations (Elastic Range)</b> . . . . . <b>C-1</b>
<b>Annex D</b>	<b>(informative) Calculation Sheets</b> . . . . . <b>D-1</b>
<b>Annex E</b>	<b>(normative) Stress Curves and Data Tables (SI Units)</b> . . . . . <b>E-1</b>
<b>Annex F</b>	<b>(normative) Stress Curves and Data Tables (USC Units)</b> . . . . . <b>F-1</b>
<b>Annex G</b>	<b>(informative) Derivation of Corrosion Fraction and Temperature Fraction</b> . . . . . <b>G-1</b>
<b>Annex H</b>	<b>(informative) Data Sources</b> . . . . . <b>H-1</b>
<b>Bibliography</b>	. . . . . <b>Bib-1</b>

# Contents

Page

## Figures

1	Corrosion Fraction	7
2	Temperature Fraction	11
3	Return Bend and Elbow Geometry	14
4	Sample Calculation for Elastic Design	21
5	Sample Calculation for Rupture Design (Constant Temperature)	27
6	Sample Calculation for Rupture Design (Changing Temperature)	31
A.1	Tube Metal Temperature Limit Process Logic Map	A-2
A.2a	Retirement Thickness Determination Process Logic Map	A-4
A.2b	Retirement Thickness Determination Process Logic Map (Continued)	A-5
A.2c	Retirement Thickness Determination Process Logic Map Continued	A-6
B.1	Ratio of Maximum Local to Average Heat Flux	B-6
E.1	Stress Curves (SI Units) for ASTM A192 Low-carbon Steels	E-5
E.2	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A192 Low-carbon Steels	E-6
E.3	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A192 Low-carbon Steels	E-7
E.4	Stress Curves (SI Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels	E-9
E.5	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels	E-10
E.6	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels	E-11
E.7	Stress Curves (SI Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels	E-13
E.8	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels	E-14
E.9	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels	E-15
E.10	Stress Curves (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels	E-17
E.11	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels	E-18
E.12	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels	E-19
E.13	Stress Curves (SI Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels	E-21
E.14	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels	E-22
E.15	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels	E-23
E.16	Stress Curves (SI Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels	E-25
E.17	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels	E-26
E.18	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels	E-27
E.19	Stress Curves (SI Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels	E-29
E.20	Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels	E-30
E.21	Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels	E-31

## Contents

	Page
E.22 Stress Curves (SI Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	E-33
E.23 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	E-34
E.24 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	E-35
E.25 Stress Curves (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	E-37
E.26 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	E-38
E.27 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	E-39
E.28 Stress Curves (SI Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	E-41
E.29 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	E-42
E.30 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	E-43
E.31 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	E-45
E.32 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	E-46
E.33 Larson-Miller Parameter vs. Stress Curve (SI Units) for A213, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	E-47
E.34 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	E-49
E.35 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	E-50
E.36 Larson-Miller Parameter vs. Stress Curve (SI Units) for A213, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	E-51
E.37 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	E-53
E.38 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	E-54
E.39 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	E-55
E.40 Stress Curves (SI Units) for ASTM A213, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	E-57
E.41 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	E-58
E.42 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	E-59
E.43 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	E-61
E.44 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	E-62
E.45 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	E-63
E.46 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels . . . . .	E-65

## Contents

	Page
E.47 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels .....	E-66
E.48 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels .....	E-67
E.49 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels .....	E-69
E.50 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels .....	E-70
E.51 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels .....	E-71
E.52 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels.....	E-73
E.53 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels.....	E-74
E.54 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels.....	E-75
E.55 Stress Curves (SI Units) for ASTM B407 UNS N08800 Alloy 800 Steels .....	E-77
E.56 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM B407 UNS N08800 Alloy 800 Steels .....	E-78
E.57 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM B407 UNS N08800 Alloy 800 Steels .....	E-79
E.58 Stress Curves (SI Units) for ASTM B407 UNS N08810 Alloy 800H Steels.....	E-81
E.59 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM B407 UNS N08810 Alloy 800H Steels.....	E-82
E.60 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM B407 UNS N08810 Alloy 800H Steels.....	E-83
E.61 Stress Curves (SI Units) for ASTM B407 UNS N08811 Alloy 800HT Steels.....	E-85
E.62 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM B407 UNS N08811 Alloy 800HT Steels .....	E-86
E.63 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM B407 UNS N08811 Alloy 800HT Steels .....	E-87
E.64 Stress Curves (SI Units) for ASTM A608 Grade HK-40 Steels .....	E-89
E.65 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A608 Grade HK-40 Steels .....	E-90
E.66 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A608 Grade HK-40 Steels.....	E-91
E.67 Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels.....	E-93
E.68 Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels.....	E-94
E.69 Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels.....	E-95
F.1 Stress Curves (USC Units) for ASTM A192 Low-carbon Steels.....	F-5
F.2 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A192 Low-carbon Steels .....	F-6
F.3 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A192 Low-carbon Steels .....	F-7
F.4 Stress Curves (USC Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels .....	F-9

## Contents

	Page
F.5 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels . . . . .	F-10
F.6 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels . . . . .	F-11
F.7 Stress Curves (USC Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels . . . . .	F-13
F.8 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels . . . . .	F-14
F.9 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels . . . . .	F-15
F.10 Stress Curves (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels . . . . .	F-17
F.11 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels . . . . .	F-18
F.12 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels . . . . .	F-19
F.13 Stress Curves (USC Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels . . . . .	F-21
F.14 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels . . . . .	F-22
F.15 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels . . . . .	F-23
F.16 Stress Curves (USC Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels . . . . .	F-25
F.17 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels . . . . .	F-26
F.18 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels . . . . .	F-27
F.19 Stress Curves (USC Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels . . . . .	F-29
F.20 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels . . . . .	F-30
F.21 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels . . . . .	F-31
F.22 Stress Curves (USC Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	F-33
F.23 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	F-34
F.24 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	F-35
F.25 Stress Curves (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	F-37
F.26 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	F-38
F.27 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	F-39
F.28 Stress Curves (USC Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	F-41
F.29 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	F-42
F.30 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	F-43
F.31-Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	F-45



## Contents

	Page
F.32 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	F-46
F.33 Larson-Miller Parameter vs. Stress Curve (USC Units) for A213, ASTM A271, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	F-47
F.34 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	F-49
F.35 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	F-50
F.36 Larson-Miller Parameter vs. Stress Curve (USC Units) for A213, ASTM A271, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	F-51
F.37 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	F-53
F.38 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	F-54
F.39 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	F-55
F.40 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	F-57
F.41 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	F-58
F.42 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	F-59
F.43 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-61
F.44 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-62
F.45 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-63
F.46 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-65
F.47 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-66
F.48 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-67
F.49 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-69
F.50 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-70
F.51 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-71
F.52 Stress Curves (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-73
F.53 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-74

## Contents

	Page
F.54 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-75
F.55 Stress Curves (USC Units) for ASTM B407 UNS N08800 Alloy 800 Steels . . . . .	F-77
F.56 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM B407 UNS N08800 Alloy 800 Steels . . . . .	F-78
F.57 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM B407 UNS N08800 Alloy 800 Steels . . . . .	F-79
F.58 Stress Curves (USC Units) for ASTM B407 UNS N08810 Alloy 800H Steels . . . . .	F-81
F.59 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM B407 UNS N08810 Alloy 800H Steels . . . . .	F-82
F.60 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM B407 UNS N08810 Alloy 800H Steels . . . . .	F-83
F.61 Stress Curves (USC Units) for ASTM B407 UNS N08811 Alloy 800HT Steels . . . . .	F-85
F.62 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM B407 UNS N08811 Alloy 800HT Steels . . . . .	F-86
F.63 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM B407 UNS N08811 Alloy 800HT Steels . . . . .	F-87
F.64 Stress Curves (USC Units) for ASTM A608 Grade HK-40 Steels . . . . .	F-89
F.65 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A608 Grade HK-40 Steels . . . . .	F-90
F.66 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A608 Grade HK-40 Steels . . . . .	F-91
F.67 Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-93
F.68 Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-94
F.69 Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-95
 Tables	
1 Minimum Allowable Thickness of New Tubes . . . . .	10
2 Summary of Working Equations . . . . .	12
3 Material Constant for Temperature Fraction . . . . .	13
4 Larson-Miller Constants . . . . .	18
5 Limiting Design Metal Temperature for Heater-tube Alloys . . . . .	19
6 Index to Allowable Stress Curves . . . . .	20
A.1 Retirement Wall Thickness . . . . .	A-7
A.2 Approximation of the Operating History . . . . .	A-8
A.3 Life Fractions for Each Period . . . . .	A-10
A.4 Future Life Fractions, Minimum Rupture Strength . . . . .	A-11
A.5 Future Life Fractions, Average Rupture Strength . . . . .	A-12
E.1 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A192 Low-carbon Steels . . . . .	E-8
E.2 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels . . . . .	E-12
E.3 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels . . . . .	E-16

## Contents

	Page
E.4 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels . . . . .	E-20
E.5 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels . . . . .	E-24
E.6 Elastic and Rupture Allowable Stresses (SI Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels . . . . .	E-28
E.7 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels . . . . .	E-32
E.8 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	E-36
E.9 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	E-40
E.10 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	E-44
E.11 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for A213, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	E-48
E.12 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for A213, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	E-52
E.13 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels . . . . .	E-56
E.14 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	E-60
E.15 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	E-64
E.16 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels . . . . .	E-68
E.17 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels . . . . .	E-72
E.18 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels . . . . .	E-76
E.19 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM B407 UNS N08800 Alloy 800 Steels . . . . .	E-80
E.20 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM B407 UNS N08810 Alloy 800H Steels . . . . .	E-84
E.21 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM B407 UNS N08811 Alloy 800HT Steels . . . . .	E-88
E.22 Elastic, Rupture Allowable Stresses and Rupture Exponent (SI Units) for ASTM A608 Grade HK-40 Steels . . . . .	E-92
E.23 Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels . . . . .	E-96
F.1 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A192 Low-carbon Steels . . . . .	F-8
F.2 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A106 Grade B and ASTM A210 Grade A1 Medium-carbon Steels . . . . .	F-12
F.3 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A209 T1 and ASTM A335 P1 Carbon-1/2Mo Steels . . . . .	F-16

## Contents

	Page
F.4 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels . . . . .	F-20
F.5 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T22 and ASTM A335 P22 2-1/4Cr-1Mo Steels . . . . .	F-24
F.6 Elastic and Rupture Allowable Stresses (USC Units) for ASTM A213 T21 and ASTM A335 P21 3Cr-1Mo Steels . . . . .	F-28
F.7 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T5 and ASTM A335 P5 5Cr-1/2Mo Steels . . . . .	F-32
F.8 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T5b and ASTM A335 P5b 5Cr-1/2Mo-Si Steels . . . . .	F-36
F.9 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels . . . . .	F-40
F.10 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels . . . . .	F-44
F.11 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for A213, ASTM A271, ASTM A312, and ASTM 376 TP 304 and 304H (18Cr-8Ni) Stainless Steels . . . . .	F-48
F.12 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for A213, ASTM A271, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels . . . . .	F-52
F.13 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels. . . . .	F-56
F.14 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A271, ASTM A312, ASTM 376 TP 316L (16Cr-12Ni-2Mo) Stainless Steels and ASTM A213, A312 TP 317L Stainless Steels . . . . .	F-60
F.15 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321 (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-64
F.16 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels . . . . .	F-68
F.17 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347 (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-72
F.18 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A271, ASTM A312, and ASTM 376 TP 347H (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-76
F.19 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM B407 UNS N08800 Alloy 800 Steels . . . . .	F-80
F.20 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM B407 UNS N08810 Alloy 800H Steels . . . . .	F-84
F.21 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM B407 UNS N08811 Alloy 800HT Steels . . . . .	F-88
F.22 Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A608 Grade HK-40 Steels . . . . .	F-92
F.23 Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels . . . . .	F-96

## Notice

### Instructions for Submitting a Proposed Revision to this Standard Under Continuous Maintenance

The American Petroleum Institute maintains this standard under continuous maintenance procedures. These procedures establish a document program for regular publication of addenda or revisions, including timely and documented consensus action on requests for revisions to any part of the standard. Proposed revisions shall be submitted to the Director, Standards Department, American Petroleum Institute, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, [standards@api.org](mailto:standards@api.org).

This addendum to API 530, 7th Edition, contains the following changes:

- Updated rupture stress data for 9Cr-1Mo material: The rupture allowable stresses the addendum have been lowered to match the values given by the constants in WRC 541, 2<sup>nd</sup> Edition.
- The limiting design metal temperature for TP304L, TP316L, and TP317L have been decreased to 593 °C/ 1100 °F to match WRC 541 maximum temperatures for designs governed by creep properties. The allowable stress curves for TP304L, TP316L, and TP317L have been extended to 816 °C/1500 °F to match WRC 541 data for short-term exposure.
- The limiting design metal temperatures for 800HT and HK40 have been increased to 1010 °C/1850 °F to match WRC 541. The allowable stress curves also extend to this value.
- New material 347LN has been added based on data from WRC 541.

# Calculation of Heater-tube Thickness in Petroleum Refineries

## 1 Scope

This standard specifies the requirements and gives recommendations for the procedures and design criteria used for calculating the required wall thickness of new tubes and associated component fittings for fired heaters for the petroleum, petrochemical, and natural gas industries. These procedures are appropriate for designing tubes for service in both corrosive and noncorrosive applications. These procedures have been developed specifically for the design of refinery and related fired heater tubes (direct-fired, heat-absorbing tubes within enclosures). These procedures are not intended to be used for the design of external piping.

This standard does not give recommendations for tube retirement thickness; Annex A describes a technique for estimating the life remaining for a heater tube.

## 2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/API Standard 560, *Fired Heaters for General Refinery Service*

ASME Boiler and Pressure Vessel Code (BPVC)<sup>1</sup>, *Section VIII, Division 1: Pressure Vessels—Rules for Construction of Pressure Vessels*

ASME Boiler and Pressure Vessel Code (BPVC), *Section VIII, Division 2: Pressure Vessels—Rules for Construction of Pressure Vessels—Alternative Rules*

ASME B31.3, *Process Piping*

ASTM A106/A106M<sup>2</sup>, *Specification for Seamless Carbon Steel Pipe for High-Temperature Service*

ASTM A192/A192M, *Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service*

ASTM A209/A209M, *Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes*

ASTM A210/A210M, *Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes*

ASTM A213/A213M, *Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat-Exchanger Tubes*

ASTM A312/A312M, *Specification for Seamless and Welded Austenitic Stainless Steel Pipes*

ASTM A335/A335M, *Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*

ASTM A376/A376M, *Specification for Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service*

---

<sup>1</sup> ASME International, 3 Park Avenue, New York, NY 10016, [www.asme.org](http://www.asme.org).

<sup>2</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, [www.astm.org](http://www.astm.org).